Design and Testing of Rotor Blades

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Objectives & Activities

Objectives:

Research on materials, structural components and the construction of wind turbines

Activities now:

Main activities on Fibre Reinforced Plastics related to the *rotor blade* of wind turbines

- Full scale Blade Tests
- Components Tests
- Research on Materials
- Design Software for Wind Turbines

Design of blades with Focus4

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What is Focus4?

- Graphical User Interface (GUI)
- Stochastic 3D Wind Field Generation
- Wind Turbine Simulation
- Blade modeling
- Fatigue and extremes analyses
- Blade buckling analyses
- Post-processing features
- Online help system

Focus blade design

1. Define the profiles of the blade
2. Define position of profiles in the blade
3. Define lines through the profiles
4. Define materials
5. From lines and radii + materials: define sections (sheets of material)
6. Define load cases
7. Run FAROB

Profiles in blade

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2. Define position of profiles in the blade
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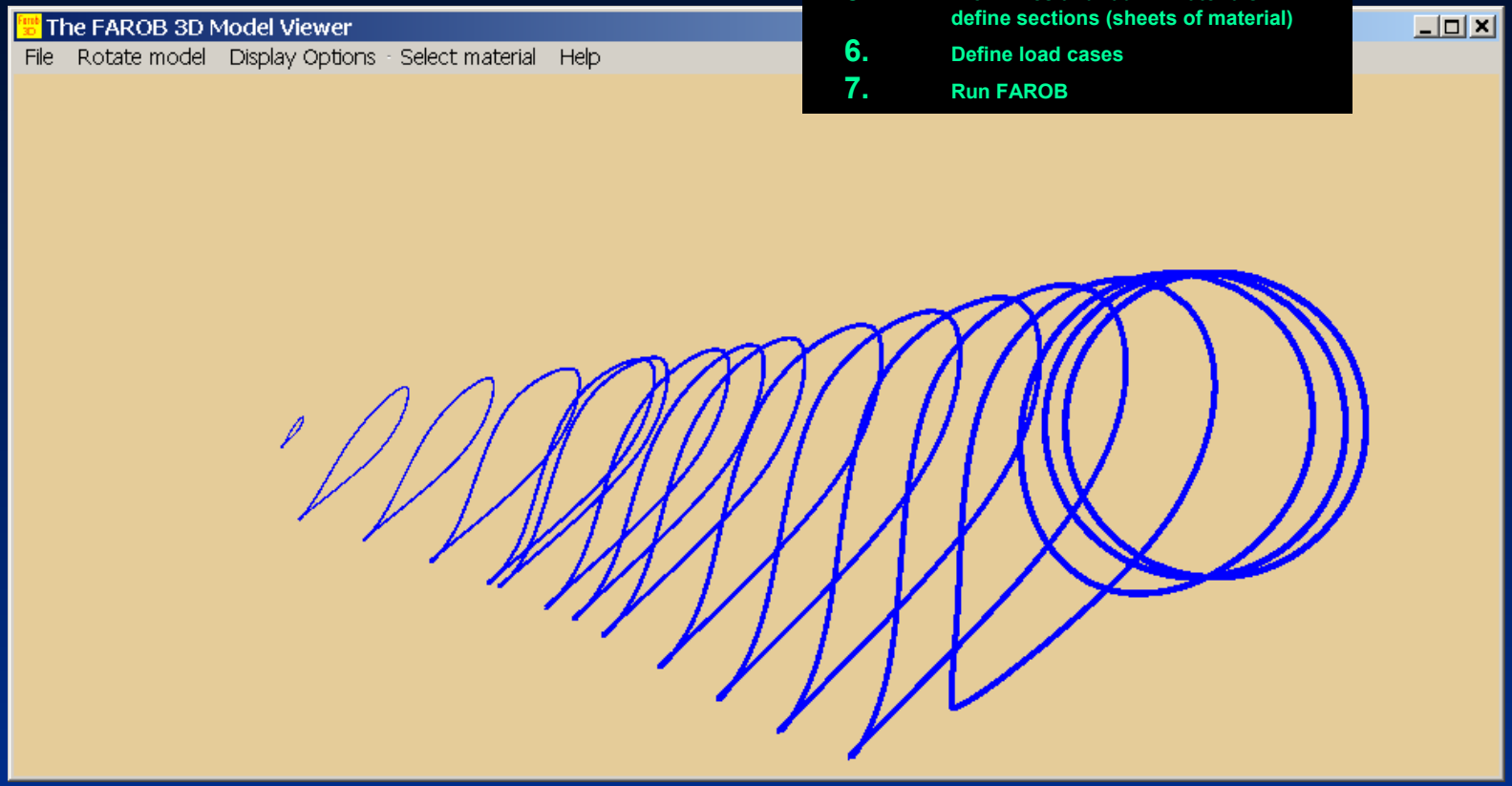
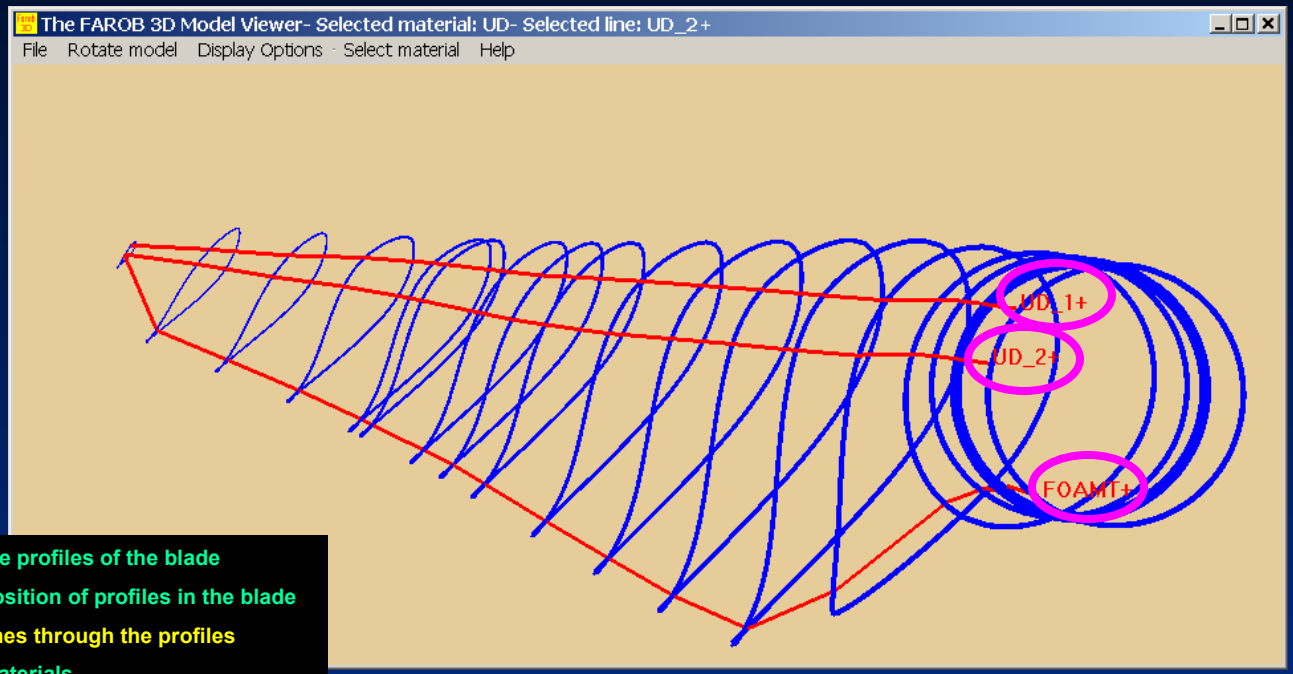


Profiles and lines in the blade



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Define Sections

```
MATERIAL FOAM
DEF SECTION FOAM_T2 SKIN/Oi
 lines                UD_2+      FOAMT+
 point      750+V       0.1
 point     3000+V      20.0
 point    22250+V      20.0
 point    22250+V      15.0
 point    28750+V      15.0
 point    28750+V      10.0
 point    32250+V      10.0
 point    32250+V       6.0
 point    33500+V       6.0
END DEF SECTION
```

```
MATERIAL UD
DEF SECTION GIRD2    SKIN/Oi
 lines               UD_1+      UD_2+
 point      750+V      0.1
 point     3750+V     33.80
 point    15750+V     33.80
 point    18250+V     31.70
 point    20250+V     30.10
 point    21250+V     29.20
 point    22250+V     28.10
 point    23250+V     26.90
 point    24250+V     25.50
 point    26250+V     21.90
 point    27250+V     19.60
```

- Give radii and lines for each sheet of material
  - Sequence: start from the mold, as in the production

1. Define the profiles of the blade
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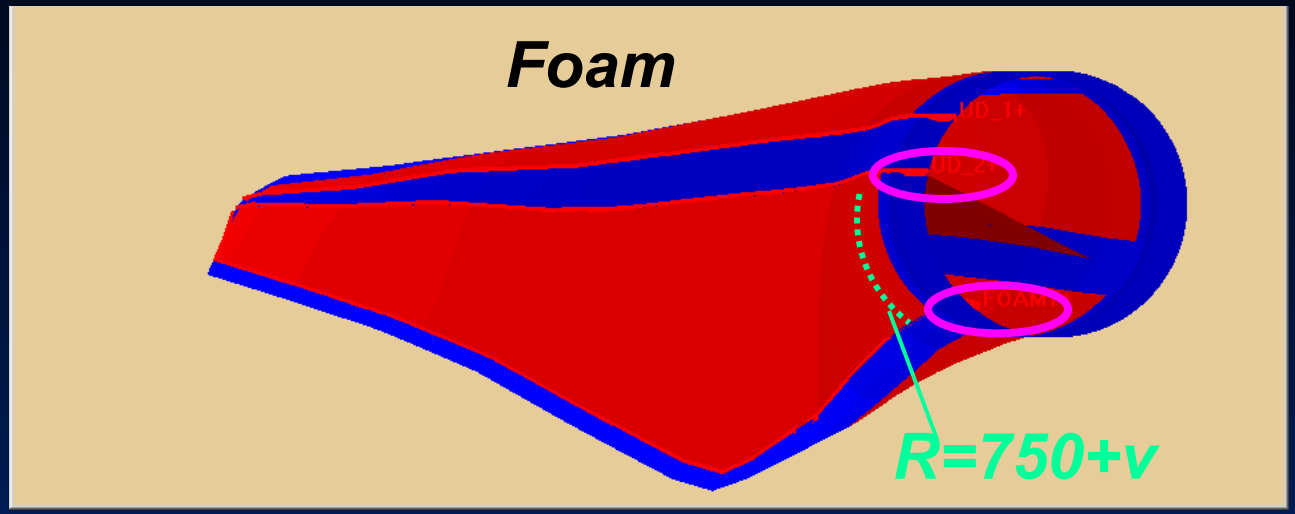
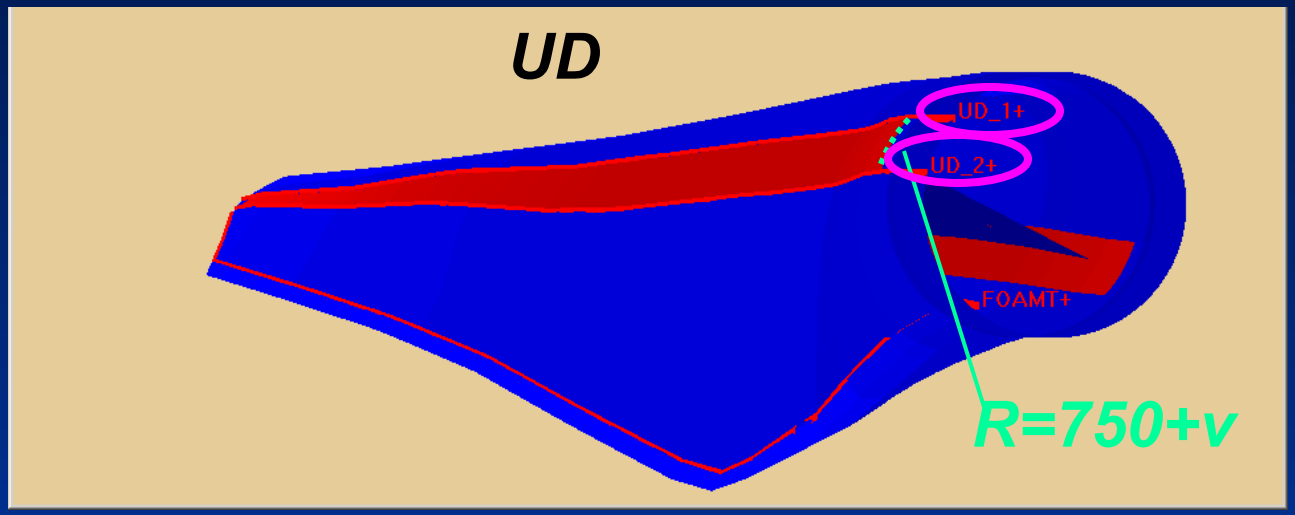
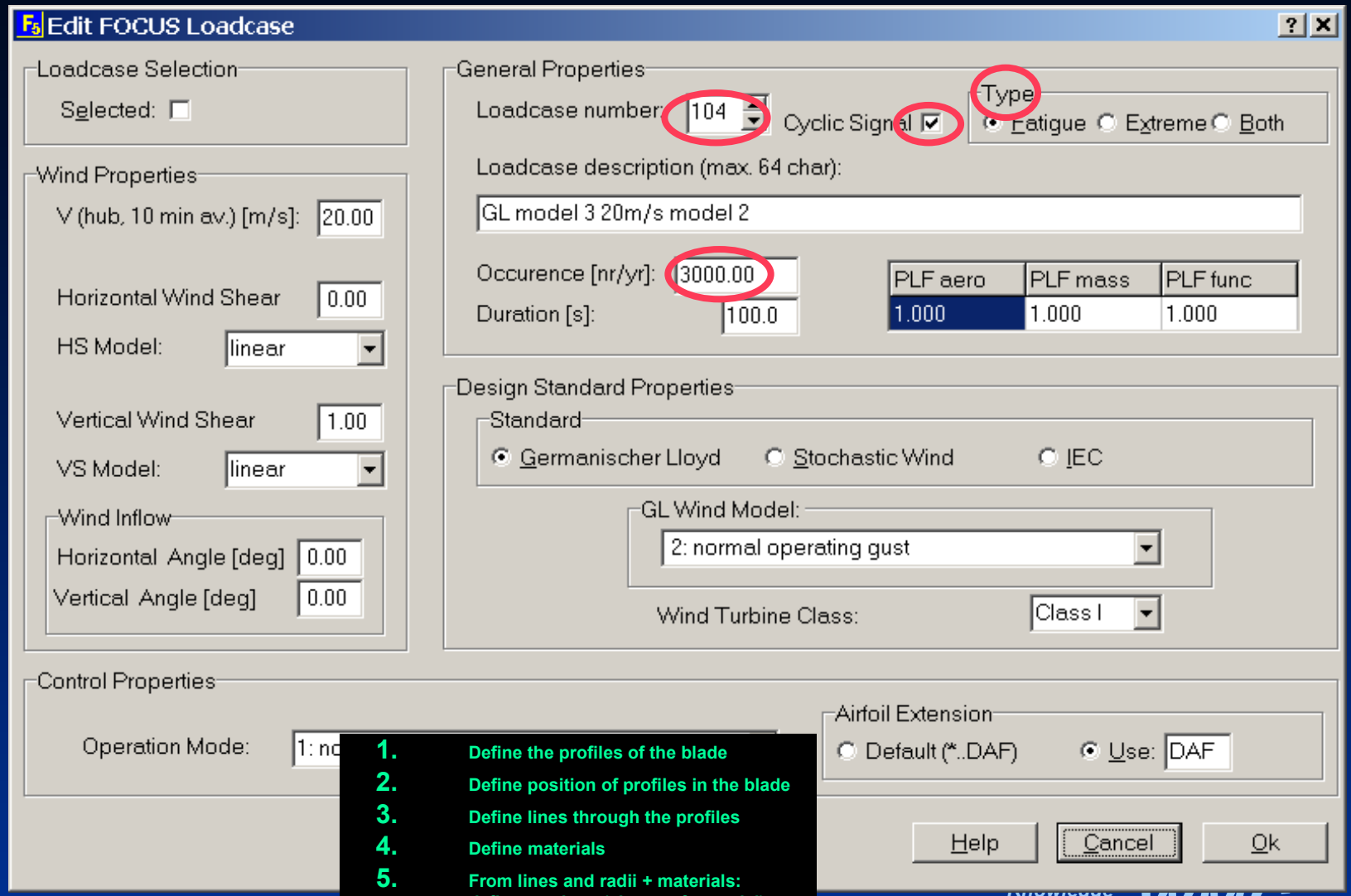
Sections defined





Load case definition



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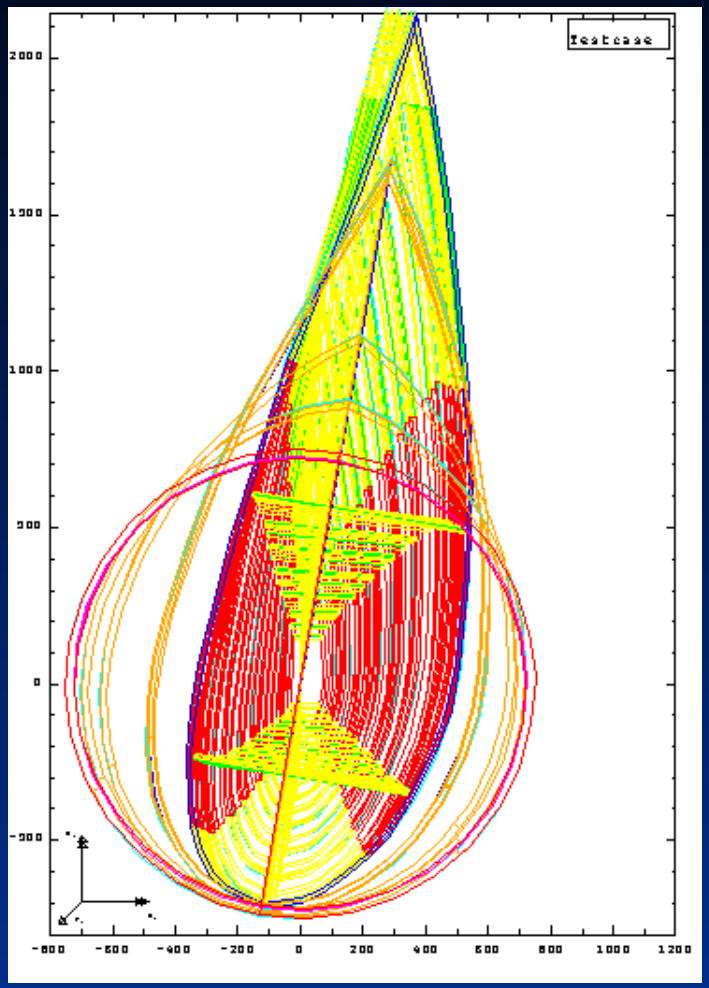
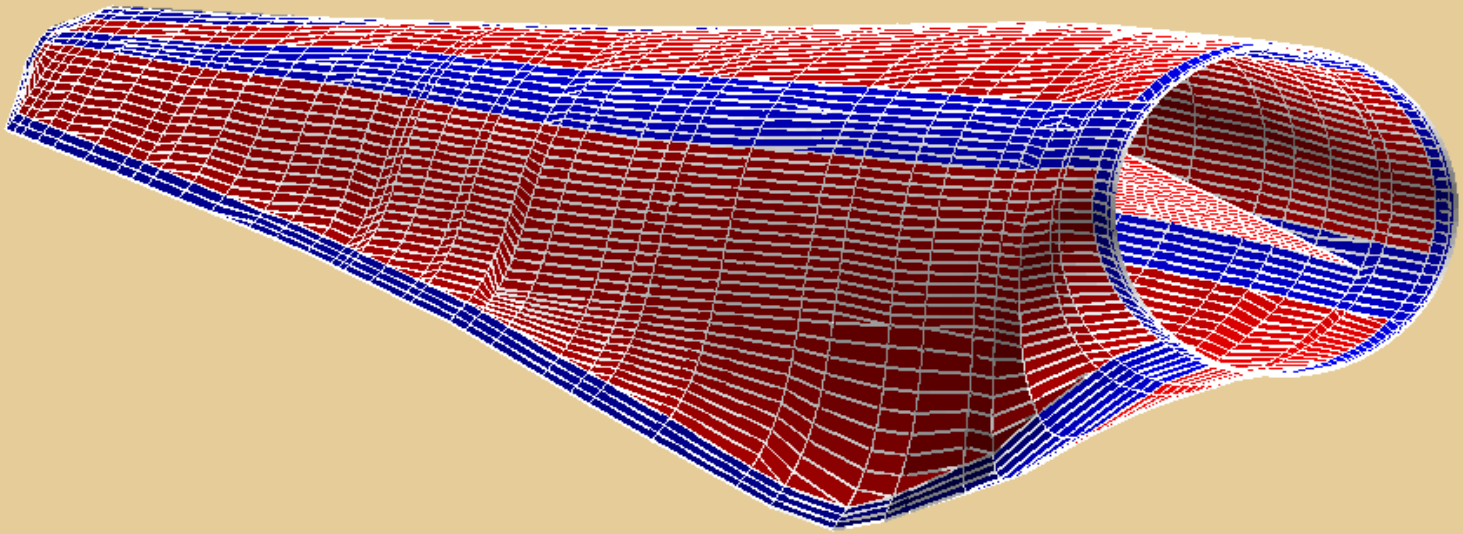
FAROB defining the blade

- Colours defined in section definition



Generated FE mesh

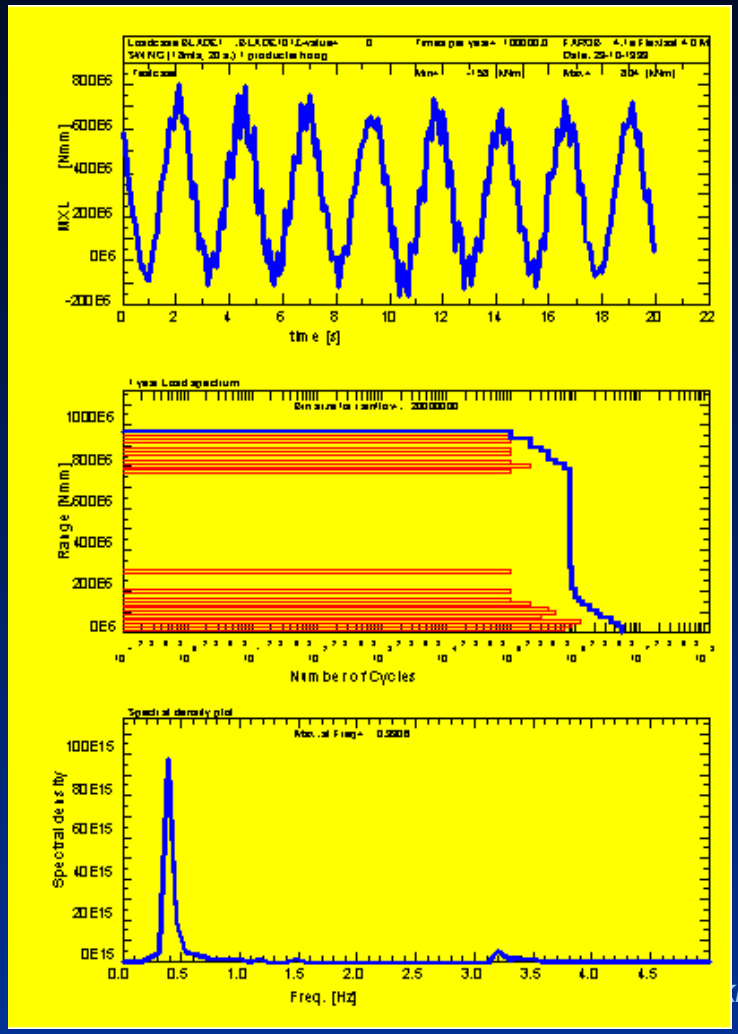
- **Supported FE codes**
  - MSC.MARC
  - MSC.NASTRAN
  - ANSYS
- **Shell elements only**
  - Geometry
  - Materials (full lay-up)



Farob Post-processing

Farob Post-processing

- Structural data plots
- Load signal plots
- Flexlast Simulation Variables plots
- Load spectra plots
- Stress spectra
- 3D Model Viewer



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Testing of rotor blades

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History: The WPS 30 Wind Turbine (1984)

The section Steel Constructions of the Faculty Civil Engineering was asked to assist in the evaluation of the constructional design of the WPS 30 wind turbine, especially the all steel rotor blade.

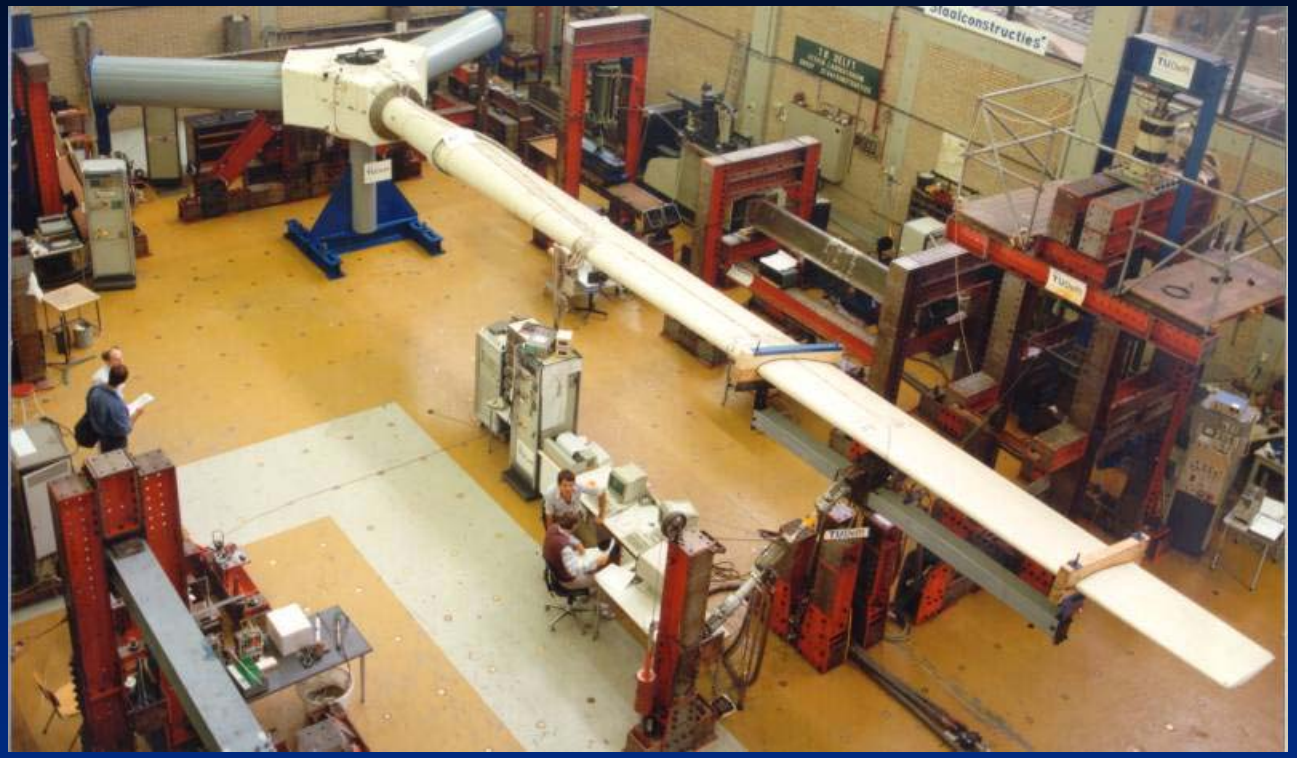
This included a full scale test on the all steel Rotor Blade.

The reasons for consulting the Section were:

- Knowledge on fatigue behaviour of steel structures
- Knowledge on experimental and numerical analysis of steel structures
- Capability to test a full scale rotor blade of 15 metres in length

History: Testing the The WPS 30 blade

Eventually WMC tooks part in the re-design and developed the full scale testing procedure for rotor blades.



In 1994 WMC was the convenor making the international IEC guideline on full scale testing of rotor blades.

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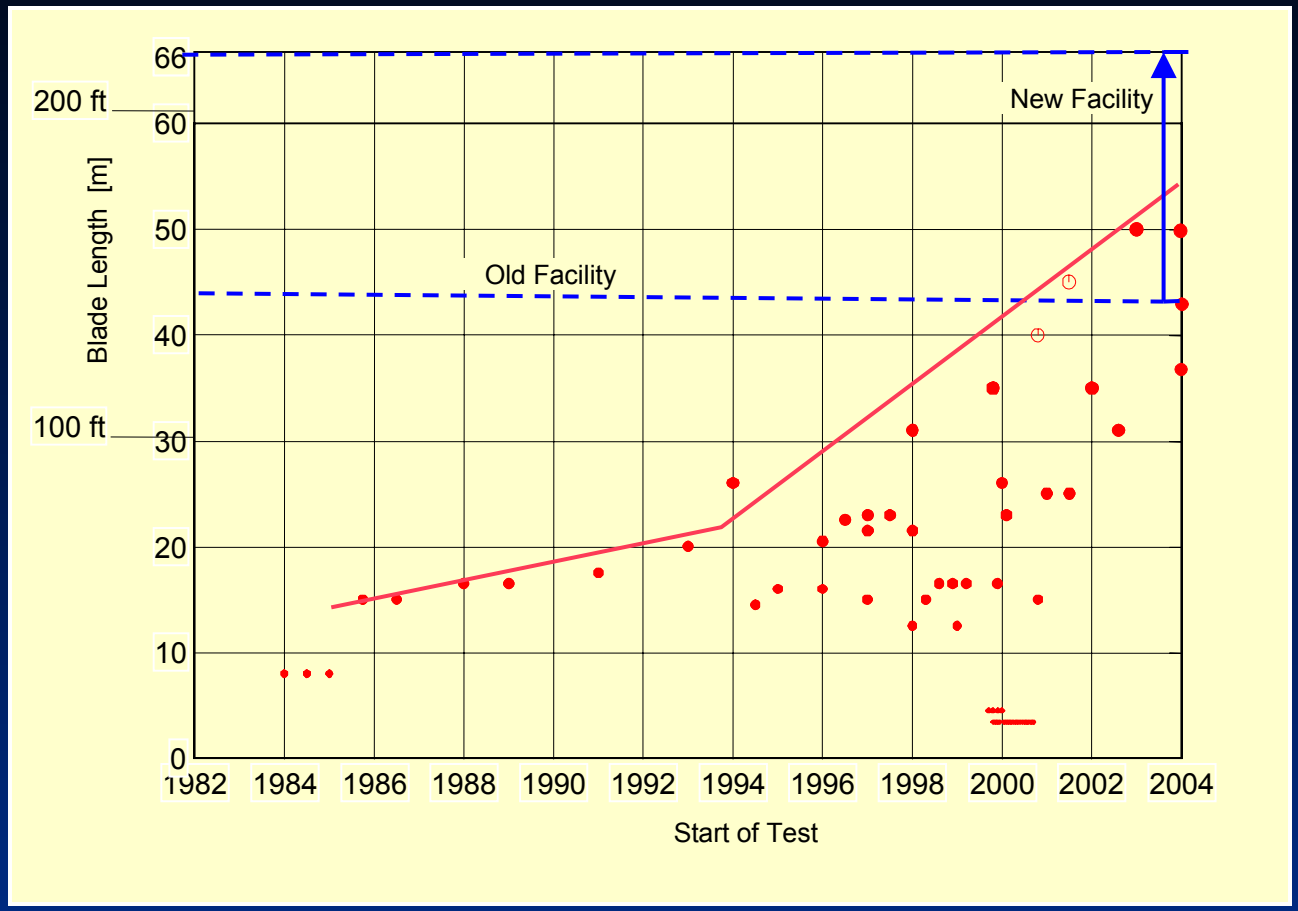
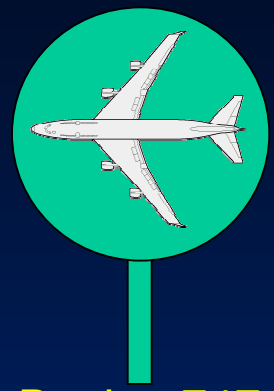
Blade Tests





Boeing 747 vs. 50 m blade length wind turbine

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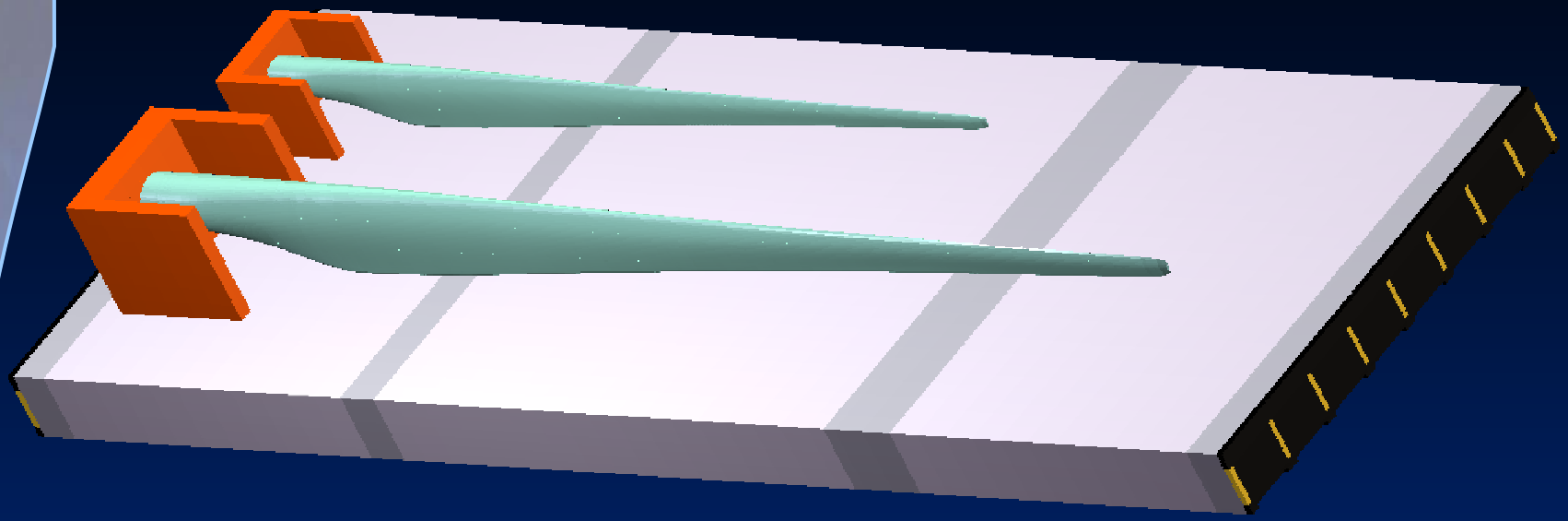
Characteristics of New Facility

- Testing hal with strong floor
  - 28x66 metres
  - Strong floor of 1,2 metres thickness
  - Large capacity hydraulic system for load application
  - Suitable for testing structures like blades up to 60 metres in length
- Laboratory for material testing
- Workshops for maintenance and building of equipment (metal, hydraulics, electro technical)
- Offices for 20-25 people
- Close to ECN test field for large (offshore) turbines

Strong Floor



- 8000 m^3 Sand removed
- 7.200.000 kg Concrete
- 500.000 kg Reinforcement steel
- 2200 achor holes

Hoisting the base plate (45 tons) for the 50 metre test stand

Hydraulic system (Ring main and pomp units)

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- Unique expertise and facilities
- Combination of Fundamental and Applied Research
- Combination of Experimental and Numerical Research
- Contracted work is carried out on project basis
- Many contacts with Institutes and industry
- Coordinator of EU projects
- World wide acknowledged expertise on Fibre reinforce plastics applicable for:
  - Wind turbines
  - Civil Engineering Structures
  - Ship Structures
- Capability to facilitate any experimental work for materials and constructions

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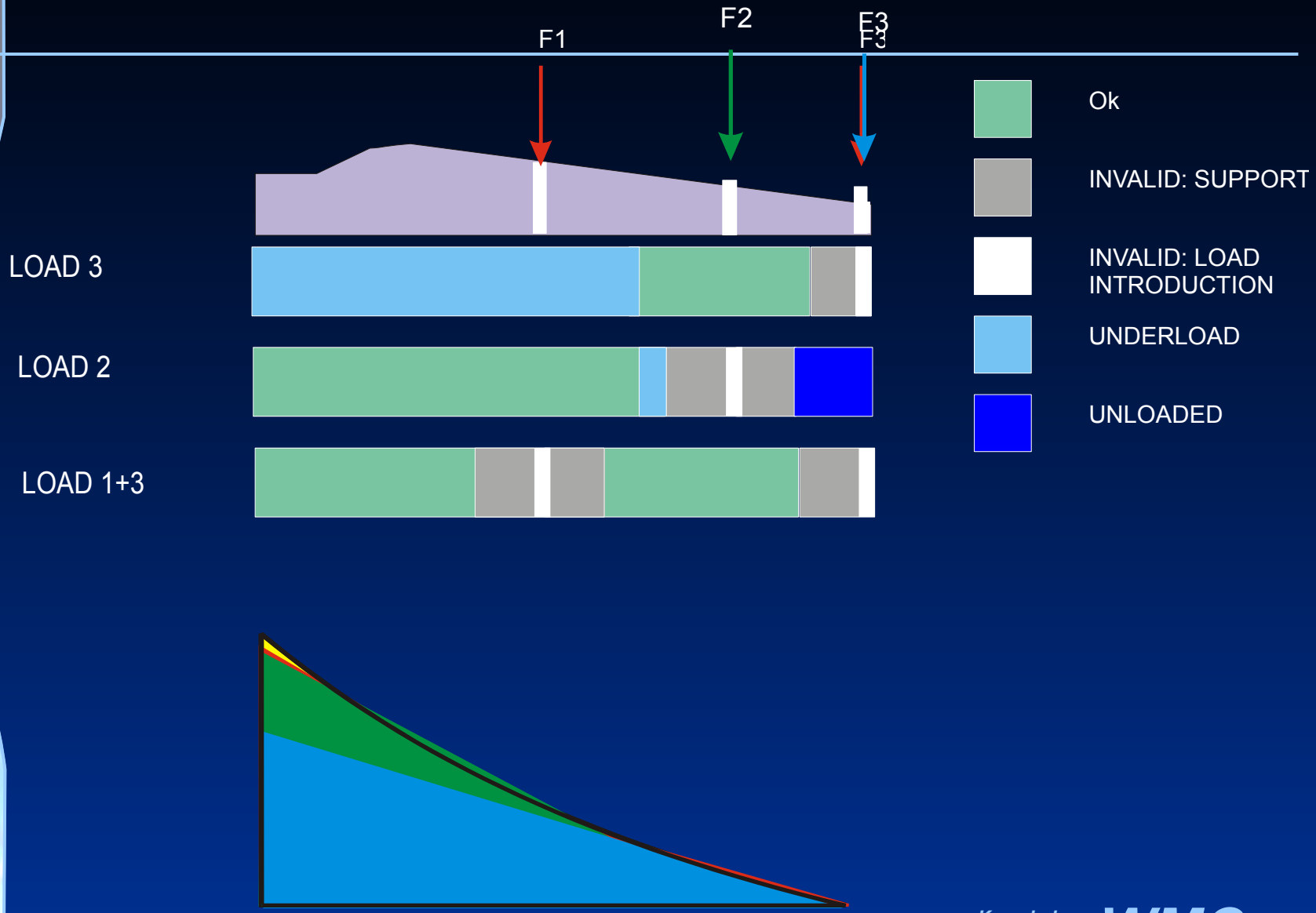
Distributed load vs. concentrated load



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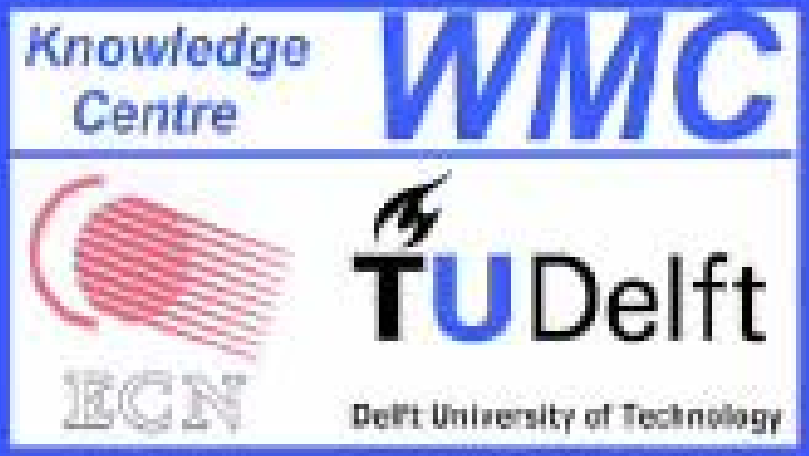
Uni-axial vs. Bi-axial fatigue test

Bi-axial

Flapwise

Edgewise



Full Scale blade testing at Knowledge Centre WMC